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# CHRONICLE OF THE WORLD HEALTH ORGANIZATION

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## SCHEDULE OF MEETINGS

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| 26-30 August | **Expert Committee on the Public Health Aspects of Water Fluoridation, Geneva** |
| 5-11 September | **WHO Regional Committee for the Western Pacific Region, Eighth Session, Hong Kong** |
| 9-14 September | **Study Group on Schizophrenia, Geneva** |
| 10-13 September | **WHO Regional Committee for Europe, Seventh Session, Copenhagen** |
| 16-21 September | **Expert Committee on Biological Standardization, Geneva** |
| 16-21 September | **WHO Regional Committee for Africa, Seventh Session, Brazzaville** |
| 16-21 September | **WHO Regional Committee for South-East Asia, Tenth Session, Rangoon** |
| 16-27 September | **Pan American Sanitary Organization Directing Council X Meeting/ WHO Regional Committee for the Americas, Ninth Session, Washington, D.C.** |
| 23-27 September | **WHO Regional Committee for The Eastern Mediterranean, Sub-Committee A, Alexandria** |
| 7-11 October * | **WHO Regional Committee for the Eastern Mediterranean, Sub-Committee B** |
| 23-28 October | **Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel, Geneva** |

* Tentative dates

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# THE CHALLENGE OF ATOMIC ENERGY

In his age-long struggle for survival, man has proved over and over again that he is an adaptable animal. Over the years he has always been ready to accept new ideas and turn them to practical use. Never has he been deterred from doing so by considerations of difficulty or danger; with courage and determination he has surmounted each obstacle in the path of progress. But perhaps in his whole history he has never had to face such a challenge as he has today—the safe exploitation of atomic power. The peaceful potentialities of nuclear energy are immense, but so are the dangers inherent in its misuse. That the nature of these dangers should be fully understood, and effective methods of avoiding them developed, has become a matter of importance for the whole human race and is a problem which calls for bold and timely action, both nationally and internationally.

It was at the end of 1954 that the World Health Organization began to take an active interest in the problem, when the Director-General of WHO called together four consultants —Dr J. C. Bugher from the USA, Dr A. J. Cipriani from Canada, Dr J. F. Loutit from the United Kingdom and Professor C. Manneback from Belgium—to advise the Organization on its future policy in this field. Here, I should like, on behalf of WHO, to pay a tribute to the late Dr Cipriani, whose untimely death was not only a great personal tragedy to his many friends at home and abroad, but is also a sad loss to the world. To him, WHO owes much, for he had a great influence on our early thinking in matters relating to the health aspects of atomic energy.

WHO's policy has changed little in the last four years. The hazards of atomic energy have been discussed repeatedly at the World Health Assembly and by the Executive Board, and the liveliness of the debates has reflected the keen interest shown in this problem.

A recent important development in WHO's atomic energy programme was the convening of a group of experts to discuss the question of the genetic effects of radiation on man—a question that has aroused considerable interest in many quarters. The report and working papers of this international group of experts have just been published by WHO, under the title " Effect of Radiation on Human Heredity ". This work brings to the medical profession up-to-date information on this complex and controversial issue, and suggests lines for future research.

The potential danger to the human race itself in man's increasing use of radiation is, of course, a long-term problem. Of more immediate, but no less urgent, concern is the question of the hazards involved in the indiscriminate use of X-rays for diagnostic purposes. This matter has been taken up by the United Nations Scientific Committee on the Effects of Atomic Radiation, which was set up by the General Assembly of the United Nations in 1955. The functions of this committee are to receive and assemble information on observed levels of radiation and on the effects of radiation on man and his environment. The UN Committee was much impressed by the total contribution of medical X-radiation to the average radiation

exposure of populations; and the conclusions reached in its statement "The Responsibilities of the Medical Profession in the Use of X-rays and other Ionizing Radiation" are obviously of direct import for the whole medical profession.

The radiologist and the general practitioner alike will not fail to appreciate the serious implications of the recent warning of the UN Committee, but it is to be hoped that they will be equally alive to other dangers, of which the scope and potentialities have not as yet been adequately assessed. Among such dangers is the hazard of exposing early human embryos to X-radiation, a risk that was pointed out by Russell & Russell[1] at the First International Conference on the Peaceful Uses of Atomic Energy, convened by the United Nations in 1955, and that was mentioned during the discussions at the Tenth World Health Assembly.[2] From the Russells' work on mice it appears that moderate doses of radiation, especially at a very early stage in the life of an embryo, may cause various deformities. If occupational irradiation does not exceed the accepted permissible weekly dose, there is very little reason to consider it a direct potential hazard to the embryo. The situation is different, however, for some types of medical application of X-rays. Therapeutic irradiation of the pelvic region would certainly involve considerable risk to an embryo in the direct beam. Also, however, certain diagnostic procedures involving unusually high dosage, particularly those using fluoroscopy, might fall into the dose range that experiments on mice have shown will, at least occasionally, produce deformities. And there is no reasonable guarantee that the human embryo is not exposed to similar dangers.

Some of the developments illustrated in this issue of the *Chronicle* mark but the first few steps of a long and difficult journey through an uncharted land. The ultimate answer to the challenge of atomic energy will rest on the present generation's alertness, ingenuity, and determination to face up to its responsibilities.

Dr Pierre Dorolle
*Deputy Director-General*
*World Health Organization*

[1] Russell, L. B. & Russell, W. L. (1956) *Hazards to the embryo and fetus from ionizing radiation.* In: *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955*, New York, vol. 11, p. 175

[2] Minutes of the fourteenth meeting of the Committee on Programme and Budget (to be published in *Off. Rec. Wld Hlth Org.*, 79)

# EFFECT OF RADIATION ON HUMAN HEREDITY

" Problems arising from the exposure of man to irradiation are extremely numerous. They bear on many aspects of his health and his children's health. To the extent that the original exposure—medical or industrial—aims at improving man's welfare, he benefits; to the extent, however, that the exposure does him bodily harm or induces gene mutations that will harm his offspring, he suffers."

Disquiet about the genetic effects of ionizing radiation began to be felt in some quarters soon after Professor H. J. Muller's demonstration in 1927 of the mutagenic action of X-rays in fruit flies. But it is only since the advent of atomic energy, with its accompanying intensive research into radiobiology, that interest in the problem has become so widespread.

Widely differing opinions have been expressed as to the possible consequences of increasing mutation, following the widespread exploitation of atomic energy and other forms of radiation. While some people appear to be unequivocally optimistic, others have voiced doubts; in particular, the much-publicized views that the use of nuclear energy is bound to increase the rates of mutation and that all mutations are necessarily harmful have given rise to considerable public alarm.

Various efforts have been made recently to assess the dangers inherent in the use of ionizing radiation and the possible means of avoiding them.

The first, conducted in the United States of America under the auspices of the National Academy of Sciences—National Research Council has resulted in two publications entitled " The Biological Effects of Radiation ": *Summary Reports*, which gives the technical findings, and *A Report to the Public*, which is intended for the lay reader.

The second attempt was a review of the existing scientific evidence on the medical aspects of ionizing radiations, and was undertaken by a committee established by the Medical Research Council of Great Britain. The Committee's final report, *The Hazards to Man of Nuclear and Allied Radiations*, was presented to Parliament and represents the most authoritative opinion on the subject expressed as yet in the United Kingdom.

The third, and most recent, report on the subject has been made at the international level by the World Health Organization. The scope of the WHO Study Group on the Effect of Radiation on Human Heredity was, however, much more limited than that of the two previously mentioned studies. " The first aim was to obtain the opinions also of authorities on genetics from countries other than those whose national committees have already stated their views. The second was to hear the opinions of a number of experts on an aspect relatively lightly touched upon in the national reports—namely, the lines of research which should be followed, in the light of present knowledge, to increase our understanding of the genetic effects of ionizing radiations on man ".

Another important body in this field is the United Nations Scientific Committee on the Effects of Atomic Radiation. This committee was established by the General Assembly of the United Nations and has wide terms of reference to receive and assemble information on observed levels of radiation and on the effects of radiation on man and his environment. The committee is due to report in July 1958. The WHO study group's report and papers were presented to the UN committee for the information of members.

The WHO study group met from 7 to 11 August 1956 at the University of Copenhagen, immediately after the First International Congress of Human Genetics. The papers presented at the meeting, as well as the formal report of the group, have just been published under the title, *Effect of Radiation*

*on Human Heredity*.[1] It is impossible here to present concisely all the technical information that has stemmed from this meeting. This account does not therefore purport to be a systematic and comprehensive summary of the information gathered for, or made available to, the study group, but merely aims at giving an idea of its main lines of approach.

## Sources of radiation

Before attempting to define the genetic problem and summarize the various ways of tackling it, a few words must be said about the sources from which man is likely to be irradiated. These can be classified broadly into two groups: the natural sources, to which he has been exposed since time immemorial (cosmic rays; radiation from the radioactive elements present in the earth's crust and in the human body itself); and the artificial sources, to which he has been exposed for only half a centry or less (X-ray apparatus for diagnosis, therapy or industrial use; nuclear reactors; luminous watches and television screens; artificial radioactive elements which have been distributed in nature as a result of man's activities). While it is, of course, in the man-made sources that the geneticist's main interest lies, a knowledge of the intensity of the radiation from natural sources is essential if the increase in the general level of radioactivity expected to result from man's increasing use of radiation in medicine and industry is to be accurately assessed.

Estimates of the doses of radiation received by individuals and by large population groups from these various sources are given in Professor R. M. Sievert's paper in *Effects of Radiation on Human Heredity*. From this it appears that, at present, the most important contributions to the average gonad dose come from cosmic rays, from the natural radiation from the earth's crust and from naturally slightly radioactive elements in man's own body, such as potassium. By far the most important man-made contribution, at any rate in the United States of America, Great Britain and Sweden, is from diagnostic X-rays. Further data on diagnostic exposures are to be found in the contribution by Dr W. M. Court Brown.

## The genetic dilemma

The pioneer work of H. J. Muller on insect populations has established beyond doubt that exposure to ionozing radiation produces increased rates of mutation, that is, increased rates of permanent alterations in the genes responsible for the determination of particular hereditary traits. In addition to such point mutations it has been shown that actual chromosome breaks may be produced, often with a consequent reduction in fertility. The first of the signed papers in the volume published by WHO is by Professor Muller and describes the work on animals and the deductions which may be drawn from it.

There is a dearth of direct information about the genetic effects of ionizing radiations on man, but geneticists agree that irradiation does induce mutations, of which some, at least, are bound to be deleterious. This point of view is reflected in the American and British reports and in the more recent WHO publication. Where opinions differ is on the question of the proportion of mutants expected to be unconditionally harmful and the relative importance of natural selection and increased mutation rates. Stated rather differently, one of the points of controversy is whether or not it is an extreme view to consider that each new mutation is unconditionally harmful and will sooner or later be eliminated by natural selection's determining a " genetic death ".

Dr T. C. Carter's contribution reviews some of the arguments likely to bring some relief to the extreme pessimist. In the first place, argues Carter, " it is commonly accepted as a working hypothesis that ionizing radiations do not induce new types of mutation, but only raise the mutation rates of existing alleles ". This is not surprising since living matter is continuously exposed to natural background radiation. An induced

[1] For table of contents, see page 264.

mutation of a type previously unknown may very well have occurred at some time in the past as a spontaneous mutation, and therefore the hypothesis that ionizing radiations cannot induce new types of mutation, like so many other hypotheses in biology, can neither be proved nor disproved. For practical purposes, however, geneticists have placed so much faith in this hypothesis that all deductions concerning the genetic hazards of exposure to ionizing radiation are based on it. Since there is no theoretical or experimental basis for assuming that man-made radiations can produce alleles of an unknown type, many of the views expressed in science-fiction and other forms of popular literature belong to the realm of fantasy.

When assessing the dangers resulting from the exploitation of nuclear energy, it is also useful to bear in mind that probably " ionizing radiation is responsible for only about one-tenth of human spontaneous mutations " and, as Carter goes on to say, " leaving nine-tenths to be accounted for, we should be unwise to ignore the possibility that chemical substances may be much more important than ionizing radiation as a cause of human mutation ".

But what is perhaps even more relevant and important than the foregoing is that a better understanding of the likely effects of new mutations will be obtained if it is remembered that " the final effect of a gene, unlike the gene itself, may be extremely variable, depending upon the other allele at the same locus, the alleles at other loci and the mass of non-genetic factors, grouped together under the term ' environment ' ". This aspect, to Carter's mind, deserves particular attention since " in no two individuals are the total genotype and the total environment identical, and therefore in no two individuals can the same allele be expected *a priori* to produce identical end effects ".

Professor L. S. Penrose, among other geneticists, has emphasized the part which genes that are disadvantageous when homozygous, but advantageous when heterozygous, may play. Such genes are well known in animal work and recently a considerable amount of evidence has been adduced that symptomless red-blood-cell sickling (the heterozygous state) and the severe sickle-cell anaemia (homozygous expression of the same gene) are examples of the same mechanism in man. It is thought that although sufferers from sickle-cell anaemia produce very few children, the trait is kept up in a population in a malarious area by the greater likelihood of survival of offspring from parents with the heterozygous sickling trait compared with individuals not affected by sickling. This is probably due to an increased resistance to *Plasmodium falciparum* malaria by the heterozygous sickle-cell carrier as contrasted with normal individuals.

Improved environmental conditions, in this case abolition of malaria, would therefore tend to bring about gradual elimination of the gene by abolishing the advantage of the heterozygous state. How far recessive genes producing other diseases than sickle-cell anaemia would be eliminated by improved environmental conditions is of course a matter for further research; the theory is full of interest and is directly opposed to the school of thought which maintains that improved environmental conditions, by allowing unfit children to grow up to reproductive age, would necessarily increase the number of detrimental genes in the population.

In his contribution, Dr Bruce Wallace discusses in some detail the two main concepts regarding the genetic structure of human populations: " that individuals of the highest possible fitness are completely homozygous " and that " the individual with the highest fitness is genetically heterozygous rather than homozygous ".

If the first concept were true for the human species, natural selection would tend to establish a population composed entirely of homozygous individuals. Theoretically, in such a case, individuals of one generation would be identical with those of the next. Since mutations would tend to prevent the population from reaching the level of fitness theoretically possible, they would have to be regarded as deleterious by definition. Muller, Crow and Haldane have all studied this concept.

According to the second concept, the individuals of a population would be as similar phenotypically (that is, from the point of view of their anatomical, physiological and psychological structure) as is consistent with the demands of natural selection, but at the same time they would be genetically diverse. " The selective coefficient of any gene in this type of population would be a function of the genetic situation prevailing within that population. Since the population consists of individuals of diverses genotypes, selection would be constantly shuffling gene frequencies and selective values, simply because of the uncertainties associated with the formation of chance gene combinations."

In contradistinction to the first, the second concept has not been studied theoretically to any appreciable extent.

The two concepts, as Bruce Wallace points out, are contrasting but are not mutually exclusive. " It may develop that one or the other is substantially correct. It may be that for some loci one is correct while for others the second applies. It is quite probable that different species differ in their genetic structure. Finally, at different times and in different places the genetic structure of a population may shift from one model to the other. "

It will be clear from the foregoing how important it is to obtain a better idea of the genetic structure of human populations. Such knowledge would, in fact, make it possible not only to assess the genetic hazards of irradiation with greater certainty, but also to formulate reasonably accurate predictions. Unfortunately, as Carter points out, this " is a problem of exceptional inherent difficulty, because we may expect that the more easily recognized genes will largely be among those with notable detrimental effects; and, conversely, that the conditionally advantageous genes will be mainly among those with minor effects and may, for just this reason, be difficult to recognize ".

These, then, are the great problems which confront the geneticist at the beginning of what is commonly called the atomic age and which so urgently need to be answered. How much increase of the natural mutation rate in man is produced by ionizing radiation? What is the role of chemical substances in the production of new mutations at the present time? Can an improved environment by indirect means bring about genetic improvement? Are all induced mutations necessarily harmful? Should predictions be formulated on the basis of equations under a model that stresses homozygosity? While not providing any final answers, the two national reports and the recent WHO publication present much useful information to those interested in the subject. No matter what the answers may be, it is surely significant that no member of the study group disagreed that the *cumulative* effect of increasing mutation rates in man is likely to be harmful to the health and welfare of future generations; and that the same conclusion, couched in different terms, was reached by both the American and the British national committees.

**Looking into the future**

It is clear, then, that knowledge of the measures which must be taken to protect large populations will largely depend on the success of future research in the field of genetics, both animal and human. Moreover, the medical profession has a particular responsibility in developing the science of human genetics, which is in most of its aspects so closely tied up with clinical and public health work.

" In recent years ", states the study group's report, " considerable quantitative knowledge has been accumulated on the basic mechanisms of genetics. There are strong grounds for believing that most genetic effects are very closely additive so that a small amount of radiation received by each of a large number of individuals can do an appreciable amount of damage to the population as a whole. There are, however, many gaps in knowledge, particularly concerning these effects in man." Attempts to obtain direct information about the effects of ionizing radiation on human heredity have so far been

derived from three main sources: radiotherapeutic experience, radiologists' occupational experience and observation of a population exposed to the radioactivity released during nuclear explosions; to date, however, none of these has yielded conclusive information.

The results of the very thorough genetic investigation of the first generation of descendants of those exposed to radiation at Hiroshima and Nagasaki have recently been published.[2] That they were largely negative was not, however, unexpected by geneticists in view of what is known about the difficulty of demonstrating mutations in either animals or man.

A further approach, using as material the offspring of patients irradiated for clinical reasons, has been undertaken in France, and an account of this interesting work is given by Dr J. Lejeune. Lejeune explains how the sex ratio in the offspring of irradiated individuals can serve as an indicator of the production of lethal genes. "It is ", he writes, " essentially in the X-chromosome that the lethal genes can be detected, through a study of the sex ratio. Owing to the chromosomal structure of sex, the X-linked lethal mutations appear in different forms according to the sex of the irradiated parent. Thus, in the offspring of a woman exposed to radiation, dominant lethal mutations linked to the sex chromosome have no effect on the sex ratio, whereas sex-linked recessives bring about a deficit of boys. The contrary is true of men, in whose progeny only the dominant lethals manifest themselves by bringing about a deficit of girls." In Lejeune's opinion, the sex ratio, although it has certain limitations, is " the most sensitive touchstone for detecting the production of lethal mutations in the first generation of children born of irradiated parents ". A proviso should perhaps be made here that the sex ratio is notoriously inconsistent in mammalian biology and so a presumption that variation in a particular direction is due to genetically induced lethals may not invariably be valid.

Animal experiments, particularly on fruit flies and mice, have been one of the richest sources of information, but how far the numerical results obtained can apply to man is a question on which much more requires to be learnt. The diverse problems involved in extrapolation from animals to man are set out clearly in the paper by Dr J. V. Neel.

To the above, the ingenuity of the geneticist has added some other sources of information, less important until now, but showing promise of being fruitful in the future. A good illustration is the study of the age-group in which fresh mutations are observed. Penrose points out the value of this approach: " Clearly, the older the parent the more likely he is to have been subjected to mutagenic influences. If the influence is background radiation, at the age of 40 the dose will have been twice that received at the age of 20. The net effect on parental age distribution of diseases in the offspring caused by background radiation alone, though definite, would be slight. The expected average increase would be scarcely more than one year above normal parental age. Marked effects confined to one or other parent have, however, been observed in several malformations. Marked increase of father's age has been found in chondrodystrophy and acrocephalosyndactyly." The reader will find some substantiating data and a discussion of the problem in Penrose's paper.

Another line of attack likely to yield valuable genetic data is the study of malformations, disease and mortality in populations with very high inbreeding rates. Dr N. Freire-Maia has drawn attention to the existence of such populations in Brazil, where much information can be obtained through the analysis of marriage records and where studies are already in progress. Although, as he says, it is unfortunate that " in the zones in Brazil where the very high inbreeding rates prevail, no analysis regarding the incidence of specific hereditary anomalies seems feasible because the level of medical practice there is lower than in the larger cities. Nevertheless, in these regions a study can be made of such population characteristics as the frequencies of abortion,

[2] Neel, J. V. & Schull, W. J. (1956) *The effect of exposure to the atomic bombs on pregnancy termination in Hiroshima and Nagasaki*, Washington, D.C.

miscarriage, stillbirth, infant mortality, malformations as a whole, etc., and should afford some interesting results. Furthermore, in Rio de Janeiro, São Paulo, and some other cities, where the inbreeding rates are probably from ten to twenty times higher than those prevailing in similar or even smaller cities in the USA . . . and where very good hospitals exist, a complete and detailed analysis is possible ". This type of research may prove to be very rewarding.

The comparison of mutation rates in two communities with different levels of background radiation is yet another way of gleaning useful genetic information, but, as Professor A. C. Stevenson explains in his paper, it is a way beset with difficulties, since background radiation normally varies so little from place to place. Not wishing to strike too pessimistic a note, however, he concludes that " serial comparisons of a number of defined areas, for several traits with carefully planned control of diagnostic standards and ascertainment, and the simultaneous collection of background-radiation information would perhaps be more valuable than a comparison between two areas only ".

A special opportunity for making such mutation-rate comparisons has been indicated by Dr A. R. Gopal-Ayengar, who points out that a population of about 100 000 has lived in virtual isolation for very many generations in Travancore, India, where the background radiation is unusually high owing to the presence of monazite—the principal ore of thorium—in the soil. " Now, in the monazite belt of Travancore ", writes Gopal-Ayengar, " we have an almost unique situation, where there would appear to be no relaxation of the forces of selection on the population, since the alleviating action of modern medical services has not found its expression to any appreciable degree. The population has been more or less stationary for generations and might be expected to show differences in mutation rates for particular traits—autosomal dominants or sex-linked recessives of the type discussed by Professor Stevenson in his paper. A control population of comparable dimensions, with similar demographic conditions and normal background radiation, exists in the nearby areas.

" An inquiry of such a nature would obviously be a long-range one, but would be well worth doing in view of the possibility of thus obtaining some direct evidence on the genetic consequences of naturally occurring high background radiation. The investigation would also be likely to shed light on the dosage relationships for doubling the spontaneous mutation rate and other cognate problems. Moreover, it might also reveal interesting somatic effects, such as the incidence of leukaemia, cancer and other conditions."

Finally, Dr H. B. Newcombe advocates an entirely new line of approach to the detection of genetic trends in public health. He points out that analysis of the routine registrations of births, marriages and deaths *by families* would yield a great deal of valuable information. The establishment of a " Family Register Index "—in other words, a family tree on an enormous scale—would make it possible to determine the incidence of any given disease condition among three groups of people: the population as a whole, the offspring of first-cousin marriages, and the siblings of affected individuals. Hence it would be possible to differentiate the genetic from the environmental causes of ill health. Newcombe stresses the essentially long-term nature of this scheme, but indicates several ways in which the same data could be applied to shorter-term genetic research.

All the above possibilities were considered by the study group and are discussed at some length in the individual contributions of the participants. The group felt that it should not recommend specific research projects, but rather indicate the larger gaps in knowledge as they appear at the present time. The following is, in brief form, the inventory of problems which the group drew up and which will need to be investigated by geneticists, nationally or internationally.

— Further study of spontaneous and artificially-induced mutation, particularly on the kinds of mutation produced by various

doses and types of radiation, applied at different stages of the life-cycle under a variety of conditions and utilizing different kinds of organisms.

— Study of the role of changes in the hereditary material of somatic cells in the genesis of leukaemia and various neoplasms. This is now possible owing to the recent developments in tissue-culture techniques.

— Study of the means of protection against mutagenic agents.

— Development of new and improved techniques for the identification of mutants, many of which remain unrecognized at the present time.

— Study of the manner of gene action. Dominance, synergism, and other forms of gene interaction, including the role of the environment, are important in appraising the effects of radiation and should be further studied in both man and animal.

— Study of factors such as natural selection in populations through the collection of demographic and experimental data. This type of research is indispensable if the genetic structure of past and present human communities is to be understood and future trends are to be predicted.

— Study of patterns of mating in human populations, such as inbreeding, and their genetic implications.

— Twin studies in man, which are known to be helpful for the understanding of many problems of human heredity.

— Determination of the frequency of diseases with a significant genetic component, with particular reference to their epidemiology. Central registration of data on human inbreeding and hereditary disease is believed to be " of the utmost importance ".

— Study of populations of special genetic interest, such as relatively stable, primitive communities, long isolated by geography or culture and communities exposed to unusually high background radiation.

— Genetic mapping of human chromosomes.

— Studies of cytochemistry and human cytology, particularly investigation of the ultramicroscopic structure and chemical composition of the heredity material and of the manner in which this is altered by irradiation and other mutagens.

— Development of new statistical methods for analysing the data obtained from research in human and experimental population genetics.

Investigations capable of throwing fresh light on all these problems will involve a very great effort in many countries and " a great expansion of general and *ad hoc* research in genetics and other fields of biology " with the closest possible collaboration between those working in the experimental and the human fields. The report of the study group emphasizes that " there is at present an insufficient number of institutions where an adequate training in genetics, particularly in human genetics, can be given ". The group believes that " medical undergraduates should all receive training in genetics and the teaching should be co-ordinated with that in radiology and in the use of radioactive substances in medicine, so that the genetic hazards of diagnostic and therapeutic procedures are thoroughly understood. Medical men training as radiologists should have specific, more advanced instruction in genetics. Health physicists, radiological physicists and radiological technicians should also receive instruction in genetics as part of their technical training.

" It seems essential that instruction in genetics should be given to all scientists, particularly those whose work is likely to involve the use of radiation and radioactive materials in research. The principles of human genetics could with advantage be conveyed to those training in the social sciences by means of formal instruction."

The study group was particularly concerned about the genetic hazards of radiation from sources used in medicine, industry, commerce and experimental science. As the report puts it: " Both as an approach to control and as providing basic background

information for relating quantitatively radiation exposure and effects on man, it is essential that methods be found of recording exposures to individuals and populations, however difficult this may prove.

" There is reason to believe that radiation exposure can be much reduced; therefore, those in charge of sources of ionizing radiations should always ensure that there is adequate justification for exposing individuals to doses however small. On account of the danger to offspring resulting from irradiation of the gonads by X-rays, consideration should be given to determining what efficient means of shielding the gonads could be devised and brought into general use. In addition, in every exposure, the X-ray beam ought as far as practicable to be directed so that a minimum of radiation reaches the gonads."

The precautions which will have to be taken if nuclear energy is to be safely exploited are manifold and only the future can show how far the human race can live up to its responsibilities in this respect. Just as important, however, as the study group stressed, is the intelligent use of diagnostic and therapeutic X-rays or radioisotopes so that their benefits may be at a maximum, and any possible long-term genetic hazard reduced to a minimum.

## RADIOISOTOPES AND INSECT BIOLOGY

Several articles in this issue of the *Chronicle* draw attention to the effects of radiation and the measure called for on the part of the authorities responsible for protecting public health, both as regards the genetic effects and the danger that may be presented by the accumulation of radioactive waste products.

In contrast with these problems concerned with radiation protection, some of the public health uses of radioactive isotopes may usefully be described. Their application in the field of medical diagnosis and treatment is well known. It is also known that thanks to radioactive elements—called " tracers " because of the work assigned to them—it is possible to trace the path followed by the main chemical groups in an organism, their reactions, their localization and their movement in living matter. For a number of years studies of the same kind have been conducted on insects, to explore problems which have remained among the most obscure in medical and agricultural entomology for lack of a satisfactory method of tackling them.

In an article which recently appeared in the *Bulletin of the World Health Organization*,[1] from which the following data have been taken, Dr L. J. Bruce-Chwatt summed up the knowledge acquired through radioisotopes of the biology of insects which carry diseases or are harmful to crops.

### Entomological research

Various experimental methods have been suggested for introducing radioactive elements into the bodies of insects without impairing their normal functions. Traces of radioactive elements have been added to feeding solutions or blood, or injected into animals stung by the insects. Investigators who have worked with the mosquito vector of yellow fever, *Aëdes aegypti*, on which numerous experiments have been carried out, prefer the larval bath. The larvae of mosquitos having completed their third instar were kept until the emergence of the adult in a feeding fluid containing radioactive isotopes. The larvae absorb these isotopes easily through the cuticle, the mouth and the anal papillae. Two radioactive elements were chosen: phosphorus-32 and strontium-89. It would have been logical to use calcium, since the larvae contain considerable quan-

[1] Bruce Chwatt, L. J. (1956) *Bull. Wld Hlth Org.*, **15**, 491

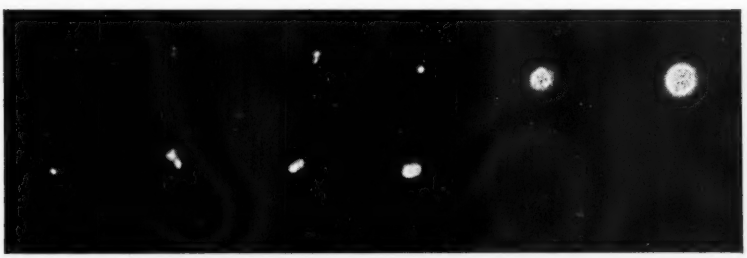
tities of it; but as the radioactive isotope of this element is difficult to prepare and to use on account of its low radiation energy, strontium-89, which is equally easily absorbed by the larvae, was preferred. The bath contained 10-20 mμc/ml of phosphorus-32 or 20 mμc/ml of strontium-89. The larvae placed in the bath develop normally and produce adults with a radioactivity of 2-16 mμc according to the number of larvae bred in the same bath and the composition of the medium. The concentration of radioactive isotopes is greatest in the legs and practically nil in the wings. Excretion is insignificant in males and in unfertilized females. This technique of collective breeding and marking has the advantage that a great number of larvae can be labelled simultaneously with a minimum of manipulation and side-effects. The amount of radioactivity remaining in the adult is sufficient for detection for one month after release. This radioactivity may be detected (to a minimum of 1 mμc) by means of a Geiger-Müller counter or by autoradiographs, with the use of the following technique: the mosquitos to be examined are mounted dry, in series, on an X-ray film, and after 24 hours images are obtained such as those shown in the figure.

In *Aëdes aegypti* concentrations of 162-200 mμc/ml of radioactive isotopes have caused lesions and functional disorders affecting the ovaries and the formation, depositing and hatching of eggs. Lesions of the same kind have been observed in *Drosophila* and certain species of *Culex* treated by X-rays. In the case of *Anopheles atroparvus*, which is less affected by such concentrations than *Aëdes aegypti*, larvae of the second generation were found to be still slightly radioactive.

Under the same conditions, females from larvae bred in a radioactive bath of innocuous concentration are twice as radioactive as males. They lose about half their radioactivity after oviposition. In parallel experiments with radioactive phosphorus and radioactive strontium, it was found that as a result of oviposition the female lost four times more phosphorus than strontium. It is easy to imagine the usefulness of such a method for studying the chemical changes associated with the formation, laying and development of eggs and the biochemical reactions which take place during these various stages.

Collective marking has made it possible to determine the dispersion and flight range of certain species of mosquitos. Table I gives a few examples. It seems that *Aëdes aegypti* is distributed more by wind drift than by its own flight. The maximum life span observed between release and capture was 28 days. Males and females travelled the same maximum distance, but the survival of males was only a fraction of that of females.

AUTORADIOGRAPHS OF A SERIES OF *A. Aegypti* LABELLED WITH P-32 AND EXHIBITING VARYING RADIOACTIVITIES



*Upper row—males:* 1.0, 1.8, 3.0, 4.0, 18.0 mμc.
*Lower row—females:* 2.5, 3.8, 5.0, 14.8 mμc.

**TABLE I. FLIGHT RANGE OF VARIOUS SPECIES OF MOSQUITO MARKED WITH RADIOISOTOPES ***

| Species | Country | Number released | Percentage recovered | Maximum flight range (miles) ** | Radioisotope |
|---|---|---|---|---|---|
| *Aëdes aegypti* | Nigeria | 276 000 | 0.11 | 0.75 | P-32<br>Sr-89 |
| *Aëdes communis* | Churchill, Canada | 3 million | 0.005 | 1 | P-32 |
| *Aëdes nigromaculis* | California, USA | 400 000 | 0.12 | 1.9 | P-32 |
| *Culex tarsalis* | California, USA | 10 000 | ? | 1 | P-32 |
| *Psorophora conformis*<br>*P. discolor* | Arkansas, USA | 50 000 | 0.09 | 6 | P-32 |
| *Anopheles bellator* | Brazil | 3 000 | ? | 0.5 | Th-226 |

* According to Bruce-Chwatt
** 1 mile = 1.6 km

It was found possible to transmit the virus of yellow fever through radioactive mosquitos and the mean virus content appeared the same as in the control mosquitos. By marking the viruses themselves, attempts are being made to clarify certain problems relating to virus transmission by insects.

### Action of insecticides

Radioactive tracer techniques, combined with paper chromatography, have already given promising results in the study of the biochemistry of the resistance of insects to insecticides. It was found that in the resistant house fly more than half the DDT absorbed was degraded to an ethylene derivative, whereas in the normal fly the insecticide was unchanged. Moreover, in 48 hours the normal flies absorbed about 50% of the DDT, whereas the resistant flies absorbed only 6%. Using DDT marked with radioactive carbon, some investigators have recently shown that the resistance results from a combination of several factors: reduced penetration of the toxic substance through the cuticle, slower internal distribution, higher speed of degradation and excretion, and, finally, an unknown protective factor which decreases the toxicity of the insecticide even when it is applied direct to the nervous ganglia.

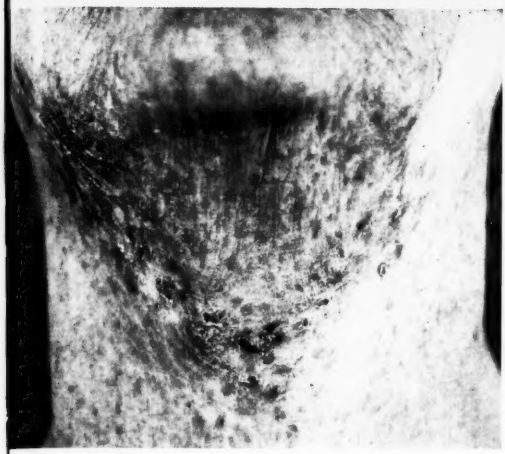
By this method it was also possible to observe the fate of DDT sprayed on crops. Bromine-labelled DDT analogue was sprayed on wheat grain, which was subsequently milled, made into bread, and fed to animals. About a quarter of the insecticide was found in the bread, but only very small quantities of DDT metabolite were detected in the excreta of the animals.

Lastly, the study of the physico-chemical qualities of insecticides and the mechanical properties of sprayers will also benefit from these new techniques. By the addition to insecticides of radioisotopes with a high gamma energy, the dispersion patterns and effectiveness of aerosols sprayed from aircraft can be accurately assessed.

# RADIATION AND HEALTH

The chief " atomic " radiations from radioactive substances are classified according to their penetrative powers as alpha-, beta- and gamma-rays. Neutrons are a type of sub-atomic particle, arising mainly from atomic reactors but also produced by machines such as cyclotrons, and can be regarded as similar to the above radiations. Formed in a different way, but essentially the same as gamma-radiation, are X-rays. All these rays have the property of ionizing matter in their path and are known generically as " ionizing radiations ", although strictly this term includes ultra-violet radiation as well.

Since the discovery of radium and X-rays at the turn of the century, the history of ionizing radiation has been chequered by the effects on health which have arisen. In the early days of radiology, over-exposure to X-rays and radium produced radiation dermatitis, which sometimes led to cancer of the skin, also aplastic anaemia, sterility and, as demonstrated lately, leukaemia. It must be remembered, however, that these ill effects occurred when radiation was dealt with in an almost completely uncontrolled manner. It is now recognized that early radiologists received unnecessarily large amounts of radiation. Examples illustrating the adverse effects that have occasionally followed ill-considered radiotherapy in the more recent past are chronic radiodermatitis 35 years after irradiation (**1**); marked keloidal formation as a result of irradiation for acne (**2**); and severe oedema of the face shortly after irradiation for mycosis fungoides (**3**).



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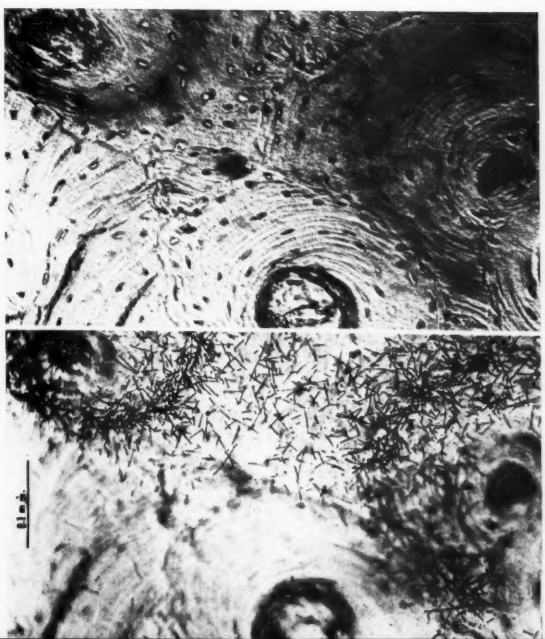

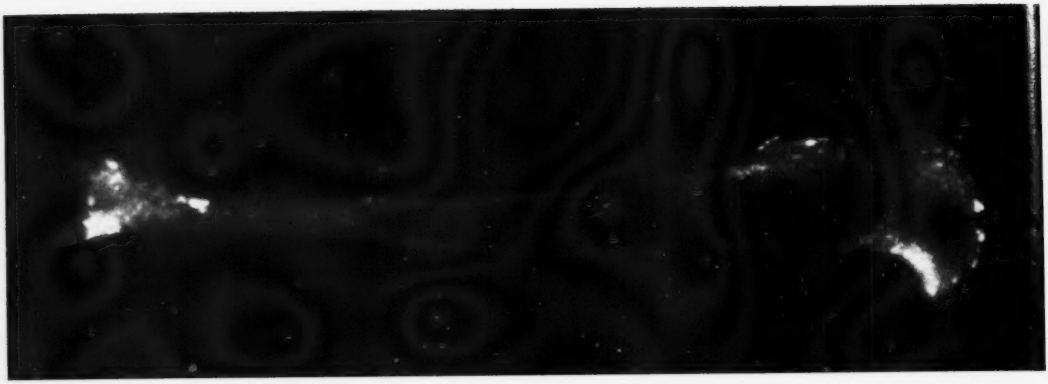

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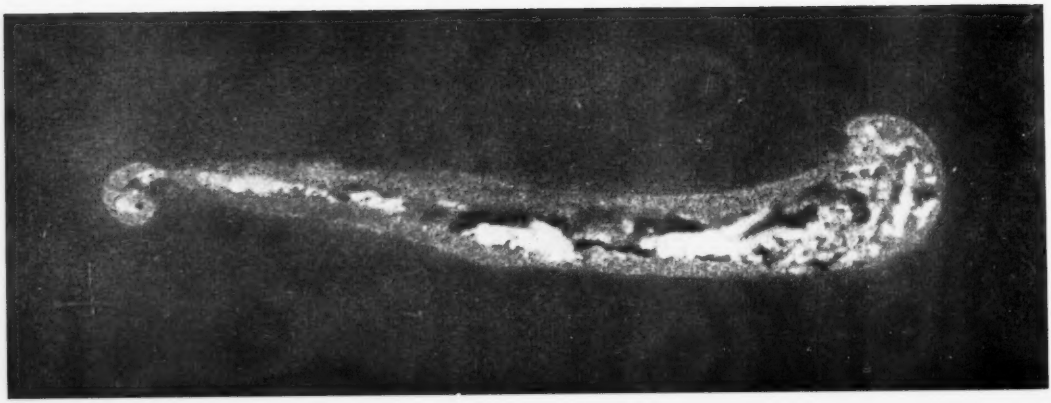

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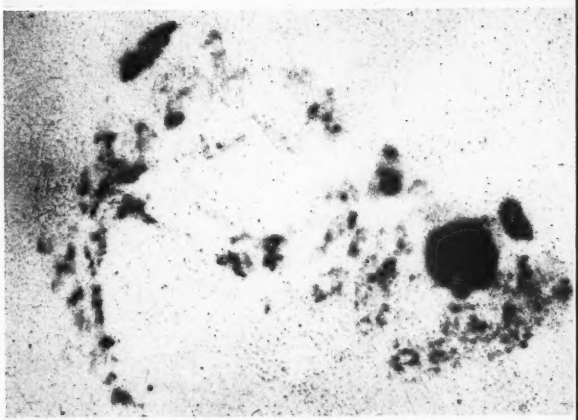
Industrial radium poisoning was observed in the early twenties in luminous-dial painters who had been in the habit of sucking the brushes charged with a diluted radium compound; after a long latent period, a number of these workers became afflicted with necrosis of the jaw, a form of aplastic anaemia, or osteosarcoma. The late development of bone necrosis or osteosarcoma has also been observed in a few individuals who had been given small doses of radium, by injection or orally. Photomicrographs were taken of a section of bone (**4**) from one of these cases, a woman who died from a bone tumour in 1951—22 years after the therapeutic administration of radium. The bottom photomicrograph was obtained by developing a thin sheet of photographic film that had been affixed to the section of bone shown above. The tracks of alpha particles from the radium atoms in the bone are visible as short needle-like streaks in the film; in other words, an autoradiograph was produced.

It should be noted, when considering the effect of the absorption of different radioisotopes by the body, that the distribution and retention of each radioelement differs, depending in fact on the chemical affinities of the particular element. An autoradiograph of a section of the leg bone (**5**) of a dog which eight-and-a-half years earlier had been injected with radioactive strontium shows both the diffuse exposure and the "hot spots" (which appear white in the illustration) where the strontium concentrated. A similar autoradiograph of a rat which had been given sodium bicarbonate labelled with radioactive carbon shows the deposition of carbon-14 in both the bone and the bone-marrow (**6**), while another shows the accumulation of a dye bearing carbon-14 in the central part of its molecule in the rat's bone-marrow (**7**). The different distribution and rates of excretion of different radioisotopes have an important bearing on their widely differing toxicity.

**8**



**9** The valuable positive contribution of radioisotopes to medicine in research, diagnosis and therapy—probably in that order of importance—has become a matter of national and international interest. For example, the WHO Study-Group on Endemic Goitre, which met in 1952, discussed the use of radioiodine in the investigation of thyroid disease. A section and autoradiograph from a simple multinodular goitre (**8**) clearly illustrates the value of autoradiography as a research tool: the autoradiograph obtained after administration of a tracer dose of radioiodine demonstrates very beautifully that the iodine-concentrating activity of the gland is confined almost entirely to one nodule. Measurement of the uptake of a tracer amount of radioiodine by the thyroid gland of a patient (**9**) provides an easy means of testing the activity of the gland. Determination of the wrist-to-wrist circulation time by means of radioiodine is another useful diagnostic technique; radioiodinated human serum albumin is injected at one wrist and the counter is placed over the other (**10**). As to the therapeutic use of radioisotopes, the running of radioactive colloidal gold into a patient's pleural cavity is an interesting example (**11**). The larger amounts of radioisotope used in therapeutic procedures make it necessary for more attention to be paid to the protection of staff: note the shielded container (**11**) and the shielded syringe (**12**) used to administer the penetrating gamma-ray-emitting isotopes.

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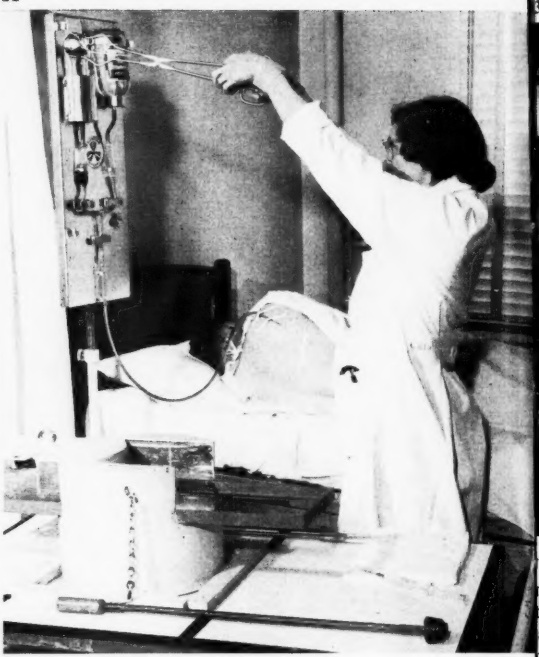

During the last few years, radioactive substances have come to be increasingly used in industry. For instance, the thickness o paper-board can be measured by means of an instrument containing a radioisotope (**13**). The widespread industrial exploitation of radiation has naturally raised the question of the protection of the workers—a subject in which WHO, jointly with the Interna tional Labour Organisation, is greatly interested. In atomic-energy establishments, far larger amounts of radioactive substances ar handled than in any other industry, and the excellent health record of the employees in such establishments shows what can b achieved in the way of protection through the limitation of radiation exposure to permissible levels. The first essential in a protectio programme is therefore to have adequate devices for measuring radiation. These may be either a portable instrument, such as the pisto monitor (**14**), or some device that is worn continually—for example, a film badge, which can be attached to each worker's clothin and developed at the end of a week or some other fixed period. Film badges give a good record of the total beta- and gamma-ra exposure of an individual over a period, but they have the disadvantage that they cannot be read at intermediate intervals to determin how much radiation has been received. Fo this purpose, pocket dosimeters of abou the size of a fountain-pen are useful (**15**) Measures are not only needed for protectio against the rays from sources of radioacti vity; precautions must also be taken agains small quantities of actual radioactive dust i the air. An apparatus is therefore required for filtering-off some of this dust fro the atmosphere and measuring its radioac tivity. It is also important to have an instru ment, such as the hand-and-foot monito (**16**), to register the presence of radioactive dust on the hands of an employee before he goes off work or takes a meal. Equally, checks must be made on floors, benches etc. to prevent spread of radioactive conta mination (**17**). Obviously, too, even smal scratches and cuts received at work must b carefully monitored for radioactivity (**18**) Note the routine film badge hanging from the pocket flap of the middle figure in this photograph.

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For much laboratory work, particularly that connected with radioactive subst nces

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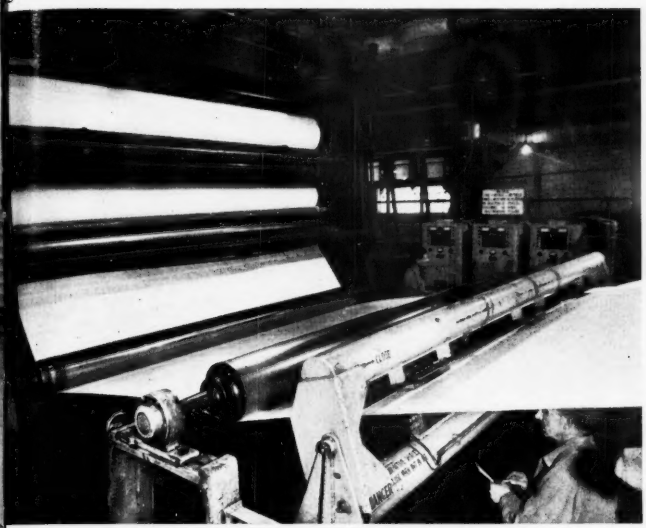

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mitting only alpha-rays, which have extremely slight penetrating powers, shielding is not necessary, but the materials must be most carefully enclosed to prevent radioactive dust from leaking out. For such purposes, what is known as a "dry box" (**19**) is used: the box is kept at subatmospheric pressure so that all leaks are inwards, and the materials are handled through the medium of long gloves let into the sides of the box. After some types of work, change of clothing is a necessary routine (**20**). The chemical processing of high-activity material is obviously best carried out by remote control (**21**), and a number of ingenious devices have accordingly been invented. For

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workers who have to enter areas that are highly contaminated with radioactive dust, two types of pressurized suits with an air line for breathing have been devised (**22**); it should, of course, only rarely be necessary to use such clothing. It must be remembered that not all the above precautions have to be observed in every case, since some of the radioisotopes are less dangerous than others; each case should be judged on its own merits, or in accordance with a national code of practice.

The transport of small quantities of radioisotopes is a comparatively simple affair, photographic film being carried nearby usually being the limiting factor. For large quantities, however, such as are used in cobalt-60 radiotherapeutic sources, very heavily shielded containers are necessary (**23**).

Many of the consequences of radiation, such as "radiation sickness", are characterized by the fact that there is a threshold below which the radiation has no effect. This does not seem to be the case, however, with the genetic effects. It is thought that however small the dose of radiation, there is some slight probability of a resultant increase in the normal mutation rate. In view of the public health interest aroused by conclusions of this sort, WHO recently convened a study group to discuss future lines of research on the effects of radiation on human heredity and to provide a small symposium of papers on this subject. On

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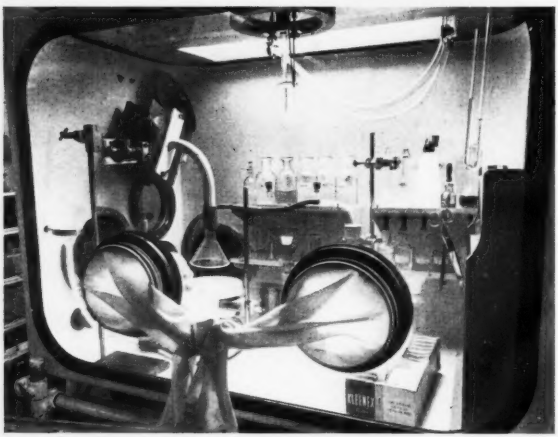

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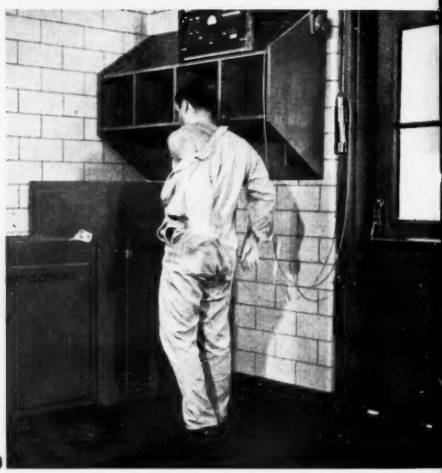

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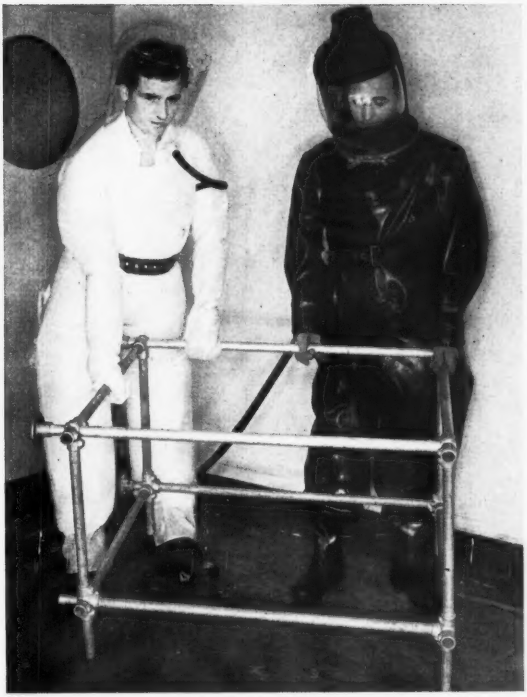
page 237 of this publication the reader will find a review of the valuable information that stemmed from the meeting of this study grou

Genetic changes after irradiation can be divided into chromosome breaks, which are relatively easily demonstrated cytologicall and point mutations. Chromosome breaks can be seen in the cells of the broad bean after exposure to X-rays (**24**): (*a*) shows broken chromosome; (*b*) a dividing cell with a " bridge and fragment " derived from a chromosome break; (*c*) and (*d*) chromosom fragments excluded from the two new cells. As these gross abnormalities occur more at high dosage and are likely to lead to ear embryological death or to reduced fertility, interest in human genetics is focused more on point mutations. Such mutations aft irradiation have been clearly demonstrated in fruit flies (**25**). For this type of illustration, of course, the more easily recognize mutations are selected, and this has led sometimes to the fallacy that " monsters " might be produced in man. This is not the gen ticist's conception; he thinks rather of an increase in the known hereditary diseases, since in experimental work no new mutation are produced which do not occur in nature. As most visible mutations are recessive the total effect of an increase in mutation ra only appears over many generations. The effect on an irradiated individual's children is likely to be minimal: in fact, " for levels radiation up to the [mutation] doubling dose and even some way beyond, the genetic effects of radiation are only appreciable whe reckoned over the population as a whole and need cause no alarm to the individual on his own account " (see ref. 1). Genetically then, the average dose to the whole population is the important figure to keep down, so that the natural background radiation fro outer space, from radioactive material in the earth's crust and from the natural radioactive elements in his own bone and flesh, whic man has been exposed to all through evolution, shall not be unreasonably increased.

The additional radiation of genetic interest which one population (that of England and Wales) was being subjected to is lis ed i the table on page 254, which has been taken from the report of a committee established by the Medical Research Cou il Great Britain (ref. 1).



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The MRC report also stated that "the upper limit, which future knowledge may set to the total dose of extra radiation which may be received by the population as a whole, is not likely to be more than twice the dose which is already received from the natural background; the recommended figure may indeed be appreciably lower than this." A somewhat similar conclusion was reached in the recent report of the US National Academy of Sciences (see ref. 2).

As occupational workers with atomic energy are only a very small minority of the population, genetic effects are less of a limiting factor in considering what maximal permissible level of radiation can be received. Such occupational levels, as well as suggestions regarding population doses, have been laid down by the International Commission on Radiological Protection, a non-governmental body in official relationship with WHO. The Recommendations of the Commission (see ref. 3) fix maximum permissible levels both for external radiation and for concentrations of different radioisotopes in air and water. They also supply a very considerable amount of other useful information on radiation protection.

There is a need for training in the new science of radiation protection which has grown up to tackle these problems. The first international training-course for health physicists, which was held at Stockholm in 1955, was sponsored by WHO in co-operation with the Swedish Government and the US Atomic Energy Commission, while lecturers came from a number of countries.

*Summary of estimated population doses of radiation to the gonads expressed as percentages of natural background* *

| *Source of Radiation* | *Approximate dose to gonads as a percentage of natural background* |
|---|---|
| Natural background | 100 |
| Diagnostic radiology | at least 22 |
| Radiotherapy | ? |
| Shoe-fitting | 0.1 |
| Luminous watches and clocks | 1 |
| Television sets | much less than 1 |
| High altitude flying | insignificant |
| Occupational exposure: | |
| Radiology and industry | at least 1.6 |
| Atomic Energy Authority | 0.1 |
| Fall-out from test explosions | less than 1 |

* Reproduced from *The Hazards to Man of Nuclear and Allied Radiations*, p. 59 (see ref. 1) by kind permission of the Medical Research Council of Great Britain.

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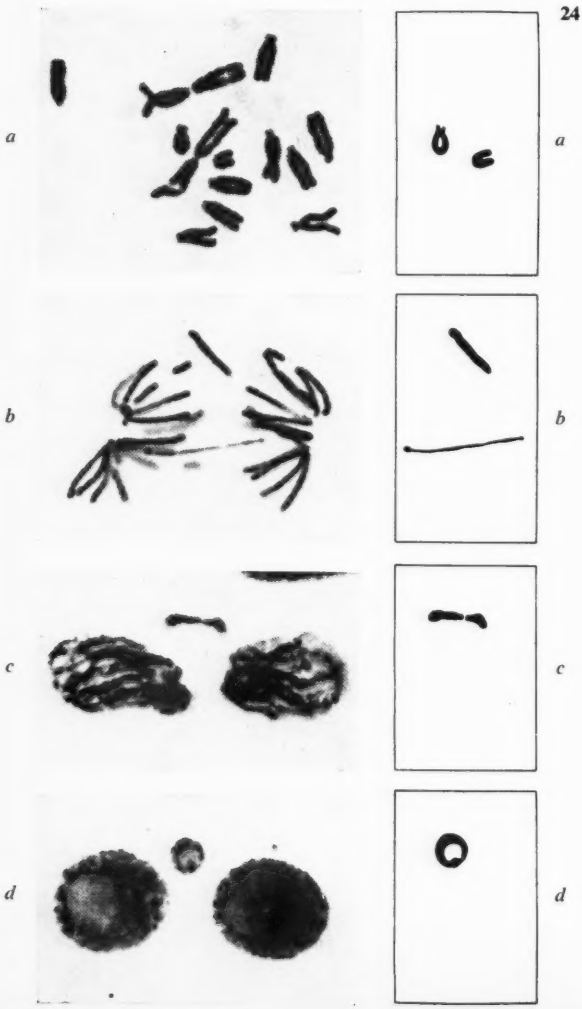


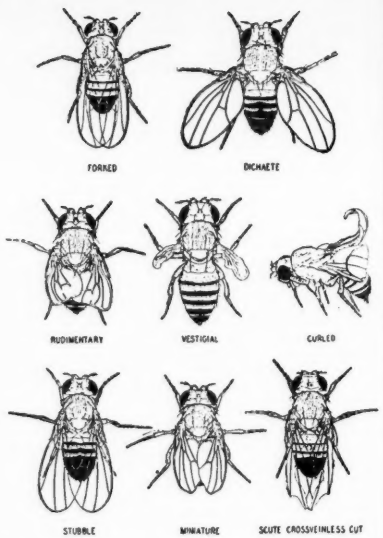


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## REFERENCES

1. Great Britain, Medical Research Council (1956) *The hazards to man of nuclear and allied radiations*, London; 2. United States of America, National Academy of Sciences (1956) *The biological effects of atomic radiation: summary reports*, Washington, D.C.; 3. International Commission on Radiological Protection (1955) *Brit. J. Radiol.*, Suppl. 6

* * *

The World Health Organization gratefully acknowledges the valuable co-operation of the following institutions, publishers and authors who have kindly made illustrations available for this article:

A. C. Allen (1954) *The Skin: A Clinico-pathologic Treatise*, The C. V. Mosby Company (1, 2, 3); Argonne National Laboratory (4, 5); J. Schubert and the Argonne National Laboratory (6, 7); Selwyn Taylor (8); United Kingdom Atomic Energy Authority (9, 10, 13, 14, 15, 17, 19, 22); United States Atomic Energy Commission (11, 12, 16, 18, 20, 21, 23); Z. M. Bacq & P. Alexander (1955) *Fundamentals of Radiobiology* (24); A. H. Sturtevant & G. W. Beadle (1940) *An Introduction to Genetics*, W. B. Saunders Company (25).

* * *

# DISPOSAL OF RADIOACTIVE WASTE

As long as nuclear energy is produced by the disintegration of heavy elements like uranium, the disposal of the waste products from the fission process will be a matter of concern to public health authorities. Industries using this form of power, plants where uranium is enriched in its fissionable isotope, and research reactors, as well as hospitals and laboratories using radioisotopes, produce waste which itself gives off radiation. If such waste were allowed to accumulate unchecked, it would soon become a menace to public health. Although fission liberates large amounts of energy, the fission products are about equal in mass to the original uranium; only a very small part of the mass is converted into energy. Even if every effort is made to recover the useful elements, it is hardly likely that it will be possible to find a use for all the by-products of the nuclear industry when atomic power is utilized in many countries. The problem of waste will remain. It is not even out of the question that it will become a factor which will limit the rational, intensive production of this form of energy. Even now, to some extent, waste-disposal considerations influence the choice of site for plants and generators. Methods of disposing of waste cannot be simple and uniform, for the residues are not homogeneous. Fission takes place in a variety of ways, so that a large number of isotopes, belonging to about 30 elements, are formed. Almost all of these are radioactive, and having half-life periods ranging from a few seconds to several decades, affinities for different organs of the human body, and very different penetrating powers, they represent various degrees of danger.

Several methods for the disposal of radioactive waste have been devised and are already being used on a wide scale in production and research centres. These methods were developed in accordance with the safety standards laid down by the national authorities responsible for the production of atomic energy and by the International Commission on Radiological Protection.

In an article which appeared recently in the *Bulletin of the World Health Organization*,[1] A. W. Kenny gave a general description of these methods for the guidance of sanitary engineers, on whom will fall part of the responsibility for radioactive-waste control. The following information is taken from this paper and from its reference sources.

## THE EFFECT OF RADIATION

None of our senses warns us of the presence of radiation in our environment since we feel no immediate pain—except, of course, if serious burns have been sustained from intense sources of radiation. It is often only after months or years that lesions, which may be serious or even fatal, are noticed.

In discussing the dangers of radiation to the human organism, it is often forgotten that, from his earliest days, man has been bombarded by cosmic rays, by radiation from the earth's crust due to the radium, thorium and potassium present, and, lastly, by radiation from his own body, principally due to the radiopotassium in the tissues. The amount of external radiation received depends on altitude and latitude. At sea level it is estimated at 0.03 roentgen (r)[2] per year, but it may be as much as 0.45 r at an altitude of 6000 metres. It also depends on geological structure, being more abundant in granites than in sedimentary rocks. Springs, particularly those in volcanic areas, may contain comparatively large amounts of radon, an emanation of radium. Sea water contains about the same amount of radium as surface water.

[1] Kenny, A. W. (1956) *Bull. Wld Hlth Org.*, 14, 1007

[2] One roentgen represents an energy absorption of 93 ergs per gram of body tissue.

The alpha-, beta- and gamma-rays emitted by radioactive elements have the faculty of ejecting the electrons from the atoms or molecules met with in their path. As they pass through matter they disrupt it, breaking chemical bonds and leaving a track of ionized or dissociated molecules. The original molecules cease to exist, and the very active ionized fragments may initiate harmful chemical reactions. According to their penetrating power, which varies with the type of radiation, the rays give rise in the tissues which they traverse, or in which they are fixed, to disturbances of different degrees of gravity. This form of energy has nothing in common with the energy produced by heat: for example, a dose of gamma-rays which could kill a man would raise the temperature of his body by only a few thousandths of a degree. Nor can its harmfulness be compared with chemical poisoning: whereas the lethal dose of tetanus toxin is 220 $\mu$g, not much more than 1 $\mu$g of radium permanently retained in the body may be sufficient to produce deadly lesions, owing to the continual liberation of the disrupting energy over a very long period. However, one microgram of radium deposited permanently in the body corresponds to a much larger dose actually administered.

The body may receive a dose of radiation in various ways: by direct external exposure to radiation, by ingestion or inhalation of radioisotopes or by absorption of radioisotopes through a wound. Not all organisms and not all tissues of the body are equally sensitive to radiation. The higher forms of animal life are more sensitive than bacteria, and rapidly developing body-cells—for example, tumour cells and reproductive cells —are particularly sensitive. Sensitivity to radiation varies from one person to another and from one age-group to another.

## ESTABLISHMENT OF SAFETY LEVELS

Cases of accidental poisoning of humans by radiation have given us some idea of the size of the dangerous doses and, hence, of the safety levels which should be established. An interesting instance of radium poisoning was observed in the USA some six or seven years after the First World War, in a factory where the luminous painting of instrument dials had been carried out during the war. The workers, not realizing the danger they were incurring, used to point the paint brushes with their lips, and it was estimated that they could have ingested 15-200 $\mu$g of radium per week. Among the 800 girls engaged on this work, there were at least 40 deaths—some from severe anaemia, others from osteosarcoma—and several cases of jaw necrosis, buccal lesions and chronic osteomyelitis. Examination of the afflicted girls and similar therapeutic cases showed that something of the order of one microcurie of radium permanently retained in the body could result in the late development of osteosarcoma.

It seems reasonable to assume that the high incidence of lung cancer observed among workers in the radium mines of Germany and Czechoslovakia (over a long period this disease has been responsible for about half the deaths of miners in certain mines) is due largely to inhalation of the radon and its radioactive daughter products in the mine atmosphere. From determinations of the average radioactive content of the atmosphere in these mines, it has therefore been possible to arrive at an estimate of the safe concentration of radon in an enclosed space.

The long-term effects suffered by the early radiologists (skin cancer, anaemia and leukaemia) clearly revealed the dangers of X-radiation and led to the tightening-up of the precautions to be observed when using X-ray apparatus.

The levels of radiation recommended by the International Commission on Radiological Protection are regarded, in the light of present knowledge, as harmless to the human body. They apply, in the first place, to the worker whose duties bring him into frequent contact with ionizing radiation. According to these standards, workers in contact with radioisotopes are not to receive more than 0.3 r per week in any one organ of the body (radioisotopes usually concen-

trate in one particular organ, so that the other organs are but little, if at all, affected); and workers exposed to X-radiation are not to receive a whole-body dose of more than 0.3 r per week, as measured in air. These standards for persons exposed to radiation have been drawn up with due consideration for the amount of ingested or inhaled radioactive matter that is absorbed by the body, for the organ in which it is concentrated, and for the rate of excretion and the radioactive characteristics of the substance in question. More recently it has been suggested that the total occupational dose received over a lifetime should not exceed a figure of the order of 200 r.[3] The levels recommended are additional to the amounts which a person receives from the environment in which he lives.

In the case, however, not of individuals or small groups of workers but of whole populations, where the law of large numbers comes into play, it has been considered advisable to lower the safety levels by a factor of 10. One of the reasons for this decision is the risk of genetic effects. Little is known as yet about the effect of radiation on human heredity, but it has been established that in all species of animals investigated irradiation increases the probability of mutations, and it is likely that the same applies to man.

## TYPES OF RADIOACTIVE WASTE

The various types of gaseous, liquid or solid waste from the atomic industry and the methods employed for their safe disposal are summarized on pages 259-260.

### *Gaseous waste*

This type of waste comes from plants in which uranium ore is crushed; from nuclear reactors cooled by air, which becomes radioactive as a result of the escape of fission products or the activation of rare gases; from nuclear-fuel processing plants; from laboratories at atomic-energy establishments; and from incinerators in which contaminated articles such as paper and clothing are destroyed. The gases are discharged into the atmosphere through tall stacks, 60-100 metres high, sometimes after filtration of the particulate matter and, if necessary, scrubbing. The surrounding neighbourhood has to be constantly monitored, taking into account the prevailing winds and the movements of the waste in the air. Around the more powerful stations, tests are made periodically of the radioactivity present in grass, in the milk of cows grazing in the area, and in the urine of the people consuming such milk.

### *Liquid wastes*

These wastes are of two types: low-activity, high-volume wastes; and high-activity, low-volume wastes. The water used for cooling reactors is an example of the former type. This water becomes contaminated by leakage of radioactive matter or by bombardment with stray neutrons, which makes the elements it normally contains radioactive. After retention for a long enough time for the short-lived isotopes to decay, this water can be regarded as a normal effluent and discharged into a river which is sufficiently large and fast-running to ensure adequate dilution.

Low-level activity is often disposed of by soakage into the ground under very carefully controlled conditions, the exact method depending very much on local geology and water levels. Geological, physical and biological checks on this method of disposal are, of course, essential.

When a radioactive effluent is discharged into the sea through a pipe-line extending some distance from the shore, it undergoes immediate dilution, the extent of which can be determined by the use of dyes or radioactive tracers. The "cloud" so formed slowly disperses and moves with the tides. Some of the radioactivity is absorbed by the

[3] See, for instance, "Maximum permissible radiation exposures to man"—a preliminary statement of the US National Committee on Radiation Protection and Measurement (*Amer. J. Roentgenol.*, 1957, 77, 910)—and the report of the Medical Research Council of Great Britain, *The hazards to man of nuclear and allied radiations*, page 80.

mud and sand, and by fish and shore-life. Bathers and people walking on the shore or eating fish, shellfish or vegetables fertilized by seaweed are thus the people whose protection must be assured. Although experience has shown that the doses of radiation received in this way from the discharge of low-level waste are very much lower than the permitted limits, it is not possible to discharge high-level liquid waste to sea, and long-term storage in small bulk must be the method to be adopted. Techniques have been devised for reducing the volume of liquid wastes by evaporation, precipitation or ion exchange. This makes it possible for such wastes to be disposed of in the form of sludge by the methods described later.

The second type of waste—the high-activity, low-volume material—is the most dangerous and raises the more difficult disposal problems. Such wastes arise in fuel-processing plants when the spent uranium is replaced by fresh uranium, and they contain the whole range of fission products. Of these, caesium-137 and strontium-90 are the most dangerous from the long-term point of view: the first because its half-life period is particularly long (33 years) and the second because, apart from having a long half-life (28 years), it settles preferably in the bones, from which site it is only excreted extremely slowly. The present method of disposal of high-activity, low-volume wastes is permanent storage in well-shielded tanks.

*Solid wastes*

When liquid wastes are concentrated as sludge they are, in effect, solid wastes, and can be dealt with as such. The highly active solid wastes, being potentially very dangerous, must be disposed of in such a way that they do not come into contact with living organisms or ground water. For this reason, they are often stored in watertight, steel-lined concrete tanks, which are buried deep in the earth, or otherwise shielded against the intense radioactivity. Slightly contaminated non-combustible material, such as glassware, may also have to be buried under controlled conditions, or put into containers and dumped in the deep ocean.

For destroying contaminated combustible waste (paper, clothing, laboratory material) from hospitals and research laboratories, incinerators are used. It has been suggested that the ash, which contains most of the radioactivity, should be incorporated in melts, to prevent it from being blown about and thus presenting a hazard. It is important that no material should be salvaged for pulping. Cases have been known where delicate physical measurements have been upset as a result of the unsuspected presence of material made from solid waste contaminated with radioactive elements.

## FURTHER RESEARCH INTO RADIOACTIVE-WASTE DISPOSAL

It will be seen that methods of radioactive waste disposal can be divided essentially into two types: dilution of radioactivity into insignificance, or concentration and storage. As regards the latter, permanent storage would be much facilitated if the waste could be concentrated into a completely insoluble form.

For example, some types of montmorillonite clay are able to act as ion exchangers and absorb most of the radioactive elements irreversibly when heated to 1000°C. Ruthenium, which is not absorbed by this clay to any appreciable extent, can be separated from it and treated by fusion in glass or ceramic material. The roasted clay in which the radioactive substances have been concentrated can be stored or buried in the ground for a long period without losing any of its absorbed elements through the action of either fresh or salt water. In other words, there is no danger of ground-water contamination. At any rate, on the basis of the results observed after several months' storage, it seems reasonable to draw such a conclusion. The method has already been used on a semi-industrial scale and is being explored further because of its many advantages.

* * *

The relation between the production of atomic energy and the disposal of the waste arising from it has been clearly expressed in one of the papers presented at the International Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1955, which included in its agenda the problem of the disposal of fission products. In the paper in question,[4] Dr E. Glueckauf of the Atomic Energy Research Establishment, Harwell, England, made the following observations, which may serve as a conclusion to this article.

" In order to appreciate fully the fission product problem it is necessary to estimate the possible expansion of nuclear energy production.

" The British atomic energy program envisages in the foreseeable future a substitution of nuclear energy for approximately 60 million tons of coal which would otherwise annually be burnt for production of electricity towards the end of this century. In order to do this, it would be necessary to burn up approximately 20 tons of nuclear fuel annually.

" From the British requirements one can estimate that world consumption of nuclear fuel may eventually reach figures of not less than 200 tons annually. On the other hand, it is unlikely that a world consumption of 1000 tons will be exceeded in the foreseeable future, as this would imply an electricity consumption per head of the world population equal to the present USA level and derived essentially from nuclear energy. From the point of view of the fission product nuisance, a world level of 1000 tons annually in the distant future is thus the most pessimistic outlook we can reasonably accept today . . . . This level of nuclear energy would be equivalent to twice the present world coal production estimated at 1500 million tons of coal. If, therefore, we can decide on ways and means to dispose, economically and without danger to ourselves and future generations, of a quantity of fission products of this order, we shall have no need to restrict later on the expansion of nuclear industries on account of the fission product nuisance."

[4] Glueckauf, E. (1956) *Long term aspect of fission product disposal.* In : *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, New York, vol. 9, p. 3

## SUMMARY OF RADIOACTIVE DISCHARGES

### A. Gaseous and Particulate Wastes

1. *Air-cooled plutonium-producing reactors and research reactors*
   Discharge to atmosphere through tall stacks, after filtration of particulate matter. Constant monitoring of surroundings. Gases may be scrubbed.
2. *Power reactors*
   Negligible discharge, except with homogeneous reactors, which incorporate their own fuel-processing plant and need same precautions as (3) below.
3. *Fuel-processing plants*
   Discharge to atmosphere through tall stacks. Fuel is allowed to " cool " for a sufficient period to allow decay of radioiodine particularly. Gases are usually scrubbed. Constant monitoring of surroundings, e.g., grass, soil, animals.
4. *Uranium recovery from ores*
   Disperse to atmosphere through stacks after filtration.
5. *Uranium-enrichment plants*
   Negligible discharge.
6. *Laboratories at atomic energy establishments*
   Disperse to atmosphere at roof level or above, sometimes with filtration.
7. *Incinerators*
   Disperse to atmosphere, usually without filtration.
8. *Hospitals and users of isotopes*
   Negligible.

### B. Liquid Wastes

1. *Water-cooled plutonium-producing reactors and research reactors*
   Cooling water is pre-treated to remove elements which become very radioactive under neutron bombardment. Discharge to river or sea after short detention to allow decay.
2. *Power reactors*
   Negligible, except with homogeneous reactors (see (3) below).
3. *Fuel-processing Plants*
   (*a*) Very active, small volume waste, containing bulk of fission products, is stored permanently after volume reduction by evaporation or other methods.

Methods of absorbing or incorporating in solids are actively being investigated. Disposal to ground is also under investigation. Removal of radiocaesium and radiostrontium by chemical precipitation would leave a relatively fast decaying waste which might be disposed of as low-activity waste after 10-15 years.

(*b*) Some medium-activity wastes have been discharged to ground. A site is used till underground water is just detectably contaminated.

(*c*) Low-activity, high volume wastes may be discharged to sea after treatment by conventional coagulation.

4. *Uranium recovery from ores and uranium-enrichment plants*
   Discharge to river after treatment for uranium recovery.

5. *Laboratories at atomic energy establishments*
   Discharge to rivers after treatment by coagulation and settling. Some waste may have to be stored, but it is usually of quite small volume.

6. *Hospitals and users of isotopes*
   Discharge to sewers or rivers without treatment, except for discarded "closed" sources.

### C. Solid Wastes

1. *Sludge from liquid-waste treatment*
   Drum and dump at sea.

2. *Contaminated equipment from atomic energy establishments*
   Suitable items may be dumped at sea. Combustible material is burnt. The rest is stored permanently.

3. *Hospitals and users of isotopes*
   Combustible material is burnt, e.g., in hospital incinerator. Solid waste is normally not unduly active and could be buried at municipal dump. It is important to avoid salvage.

## RESPONSIBILITIES OF THE MEDICAL PROFESSION IN THE USE OF X-RAYS AND OTHER IONIZING RADIATION

*The statement reproduced below was prepared by the United Nations Scientific Committee on the Effects of Atomic Radiation. Although it is addressed primarily to those who control, in whatever capacity, the medical and occupational radiation of man, the statement is likely to be of topical interest to the public health worker.*

The United Nations General Assembly, being aware of the problems in public health that are created by the developments of atomic energy, established a Scientific Committee on the Effects of Atomic Radiation. This Committee has considered that one of its most urgent tasks was to collect as much information as possible on the amount of radiation to which man is exposed today, and on the effects of this radiation. Since it has bcome evident that radiation due to diagnostic radiology and to radio-therapy constitutes a substantial proportion of the total radiation received by the human race, the Committee considers it desirable to draw attention to information that has been obtained on this subject.

Modern medicine has contributed to the control of many diseases and has substantially prolonged the span of human life. These results have depended in part on the use of radiation in the detection, diagnosis and treatment of disease. There are, however, few examples of scientific progress that are not attended by some disadvantages, however slight. It is desirable therefore to review objectively the possible present or future consequences of increased irradiation of populations which result from these medical applications of radiation.

### General survey of the irradiation of human beings

Man has always been exposed to some irradiation from natural sources. To this has now been added, as a result of modern discoveries and the applications of ionizing

radiation and radioactivity, certain forms of artificial irradiation.

Natural irradiation is due to:

(1) Cosmic radiation;

(2) " Background " gamma radiation from radioactive substances present locally in the earth, rock or building materials, and from disintegration products of radon in air;

(3) Radiations emitted from natural radioelements such as potassium 40, radium, radon and carbon 14 which are incorporated in the body.

The amount of this natural radiation varies with locality, but has been estimated as usually delivering between 70 and 170 mrems per year to the gonads. Of this total, the major contributions are of about 45% from local gamma radiations, 30% from cosmic rays and 20% from body potassium 40.[1]

Artificial irradiation is derived from:

(1) The contamination of the environment, the atmosphere, or water by radioactive waste from atomic industries or from users of radioelements;

(2) The radioactive fallout, at greater or lesser distances from the source, or radioactivity resulting from the explosion of nuclear devices;

(3) The occupational exposure of certain groups of workers: medical practitioners, radiologists, dentists, nurses, atomic energy workers, uranium or thorium miners, and the industrial or scientific users of radiation generators or radioactive isotopes;

(4) The medical use of X-rays, other ionizing radiations and radioelements in the detection, diagnosis, investigation and treatment of human diseases;

(5) The use of certain devices which emit radiation, such as television receivers, watches with luminous dials, and the X-rays generators used for the purpose of fitting shoes.

The amount of artificial radiation must vary considerably in different countries and we have inadequate information as to the over-all significance of these factors. In certain countries where estimates have been made, it appears that the greatest gonad irradiation of the population is due to diagnostic radiological procedures, the amount from this source about equalling that from all natural sources in certain instances. The total present contribution from occupational exposure, from the products of atomic industries, from radiotherapy and from the radiating devices mentioned above is likely to be considerably smaller. That from radioactive fallout to the gonads appears at present to be in the region of 1% of the natural gonad irradiation in most areas.[2]

Both the magnitude and the significance of these various sources are under review by the Committee. Since medical irradiation accounts for a substantial if not the major proportion of all artificial exposure, it is important that its magnitude should be known accurately for different countries and circumstances. The possibility of making such an assessment depends upon the help of the medical profession, and particularly on the adequacy and availability of records kept by doctors, dentists, and organizations responsible for the use of ionizing radiation.

**Radiation hazards**

The medical use of radiation is clearly of the utmost value in the prevention, diagnosis, investigation, and treatment of human disease, but the possible effects of this irradiation of individuals require examination.

Generally speaking, the irradiation of living beings may produce radiobiological effects either on the irradiated individual himself or, through him, on his descendants; the former being termed somatic and the latter genetic effects. Somatic effects vary according to the different organs or tissues affected, and range from slight and reversible disturbances such as cutaneous erythema to the induction of leukaemia or of other malignant diseases. The possible reversibility of the somatic effects of radiation

[1] From reports sent by India, Sweden, the United Kingdom, and the United States of America.

[2] According to the reports sent by the United Kingdom and the United States of America.

received in small doses or at low dose rates encourages the belief that there are permissible doses of radiation which will not cause completely irreversible or significant somatic damage. The threshold for occasional somatic damage may, however, prove to be low. In the case of genetic effects, on the other hand, there may be no threshold. These effects increase with a frequency corresponding to the total amount of radiation received by the germinal tissues, and in the great majority of cases, are adverse.

Many other factors complicate the interpretation of radiobiological effects. The differences between whole and partial body radiation, between a single exposure and continuous irradiation, or between the effects of different types of radiation are still imperfectly understood. Biological differences in the radiosensitivity of various tissues, or of the tissues of people of different age or sex, obviously influence the nature of radiation hazards. It is clear, however, that any radiation of gonads, and any substantial irradiation of other tissues, involve a chance of significant damage which requires assessment.

**General recommendations**

The radiological profession, through the International Commission on Radiological Protection,[3] has undertaken a valuable and responsible duty in defining maximum permissible limits of exposure for the main radiation hazards.

The establishment of these maximum permissible levels for those who are occupationally exposed to radiation depends on the view that there are doses which, in the light of our present knowledge, do not cause detectable somatic injury in the individual irradiated; and on the consideration that the number of individuals concerned is small enough for the genetic effects on the whole population to be negligible. For the gonads, or for irradiation of the whole body, the levels are such as to exclude doses greater than 0.3 rem in any week or 3.0 rem in any 13 weeks, or a sustained irradiation rate greater than 5 rem per year. These values imply that no total dose of over 50 rem will have been received by the gonads by the age of 30, or of over 200 rem by the whole body by the age of 60, in any occupationally exposed person.[3]

As regards irradiation of the whole population, it is considered prudent to limit the average dose to germinal tissues from artificial sources to the order of magnitude of that received from all natural sources.

In considering the extent to which the population is irradiated for medical purposes, it is essentially the genetic hazard which is involved although it seems possible that in certain circumstances somatic injury may occur occasionally after low doses of radiation arise. Otherwise, the relevant dose is that indicating the mean gonad irradiation among the population as a whole up to the end of the average reproductive period.

The extent of such genetic irradiation from diagnostic procedures has been found to be equal to at least 100% of all natural radiation in two countries,[4] and that from a third equalled at least 22% of this figure.[5] Even before obtaining more exact values for these and other countries, it is clear that the exposure can be substantial in countries with extensive medical facilities, and that it is essential to consider any ways in which this exposure could be reduced without detriment to the existing or developing value of medical radiology.

The Committee is therefore anxious to obtain the help of radiologists in suggesting through appropriate governmental channels any methods by which this total exposure could be reduced and in estimating the amount of reduction that might be expected from any such methods. In particular it would be valuable to know how much the radiation to the gonads could be reduced: (*a*) by improved design or shielding of equipment, (*b*) by fuller training of any individuals

[3] See the report of the International Commission on Radiological Protection, published in the *British Journal of Radiology* —Supplement 6, of December 1954, in the *Journal Français d'électro-radiologie*—No. 10, of October 1955, etc.

[4] Sweden, United States of America

[5] United Kingdom

using radiographic or fluorscopic equipment, (*c*) by any local shielding of the gonads that is practicable, especially during abdominal or pelvic examination, (*d*) by the use of techniques involving radiography rather than fluorscopy when full information can be obtained by this means, (*e*) by improvement of administrative arrangements designed to obviate unnecessary repetition of identical examinations of the same subject, (*f*) by a general study of certain medical conditions such as that of peptic ulcers, to identify the circumstances in which the establishment of a radiological diagnosis has or has not a definite influence upon the treatment or prognosis given.

# *Notes and News*

### Portable instrument for comparing national X-ray standards

To compare radiation results obtained in clinical and research institutions throughout the world a uniform yardstick for measuring radiation is necessary. Some countries now maintain standard instruments for the calibration of the instruments used in radiation centres: others are preparing such standards. Often, however, these standard instruments are too fragile and too bulky for shipment so that direct comparison is difficult. To overcome this difficulty the United States National Bureau of Standards has constructed a small portable ionization chamber capable of great accuracy. Accessory equipment includes a gamma-ray source and fixed geometry for checking the calibration constancy of the small chamber, and a set of calibrated diaphragms and capacitors for comparing with those of the national standard.

UNESCO, WHO and the United States National Bureau of Standards are planning to make this instrument available on temporary loan to any country upon request. UNESCO is providing the requisite funds for the purchase, maintenance and transport of the equipment, while WHO will furnish the technical expert whose duty it will be to demonstrate its use. Standardization by means of such an instrument has been endorsed by the International Commission on Radiological Units and Measurements and also by the United Nations Scientific Committee on the Effects of Atomic Radiation.

It is of importance that the rœntgen unit of radiation should be the same in each country, not only for the purpose of comparison of therapeutic X-ray doses, but, in view of the interest at the present time in doses received by whole populations from diagnostic X-rays, to ensure that surveys of doses received from such X-rays are also comparable in different countries. From the point of view of radiation biology it is most important that experimental X-ray doses are comparable, and the same applies to many other scientific uses of X-rays.

WHO has been interested in these problems since a Study Group on Radiological Units and Radiological Protection was arranged by the Organization in April 1956. This group made recommendations for WHO's consideration on a wide range of subjects, including X-ray and radioisotope standards, training in radiation protection work and the medical use of radioisotopes, and radioactive waste disposal. More specifically, however, the recommendations led to the present plan, which harmonizes well with WHO's work of biological standardization in other therapeutic and diagnostic fields.

### Conference on Research uses of Radioisotopes

Following a preliminary meeting of experts from eight countries, held in Paris from 14-15 January 1957, UNESCO is organizing an International Conference on the Utilization of Radioisotopes in Scientific Research,

which will take place also in Paris in the last two weeks of September 1957. The World Health Organization, together with the Food and Agriculture Organization, the World Meteorological Organization, and the European Nuclear Research Centre, is collaborating with UNESCO in the preparatory work for the meeting and is providing for two consultants to give evening lectures on problems of radiation protection.

The Conference aims to bring together more than a thousand experts from all over the world, for the purpose of a broad exchange of information on the various uses of radioisotopes in research. The last conference of this nature was held in 1954, at Oxford, England, under the auspices of the United Kingdom Atomic Energy Authority and, since then, substantial advances have been made, notably, as regards irradiation techniques for the production of radioisotopes.

The Conference is expected to subdivide into two main groups, dealing broadly with the utilization of radioisotopes in research in the physical sciences and in the biological sciences, respectively. WHO's chief interest as regards this Conference lies in the use of radioisotopes in basic medical research, including work on animal and human physiology and nutrition.

**Post-graduate training in atomic energy**

The coming generations of medical and public health personnel must be prepared for the new responsibilities they will have to assume in the future as a result of the advent of atomic energy. Hence, the introduction without delay of radiation biology and radiation medicine into the training of public health workers is a matter of timely importance.

The WHO Expert Committee on Professional and Technical Education is to meet in Geneva from 23 to 28 September 1957, for the express purpose of studying and exchanging experience on this matter and of drawing up a report for the information of public health educators. The members of the group will be: Professor Gaylord Anderson (United States of America), Dr John C. Bugher (USA), Professor G. Burger (Netherlands), Professor J. Coursaget (France), Sir Ernest Rock Carling (United Kingdom), Dr C. P. Straub (USA), and Dr Masao Tsuzuki (Japan).

The main subjects of discussion will be: knowledge required by various categories of public health workers; nuclear energy teaching in public health courses, including preservation and sterilization of food, drugs and biologicals, and tracer uses of radioisotopes; contamination, disposal of waste and protection from radiation; organization of the curriculum, including formal and practical teaching; and short-term refresher courses.

The report of the committee will be submitted to the WHO Executive Board at its January 1958 session; subject to approval for publication, it will be printed shortly thereafter in the *WHO Technical Reports Series.*

# *Review of WHO Publications*

*Effect of Radiation on Human Heredity: Report of a Study Group convened by WHO together with Papers presented by Various Members of the Group.* Geneva, 1957, 168 pages.

Price: £1, $4.00, Sw. fr. 12.—.

The conclusions and findings of the Study Group on the Effect of Radiation on Human Heredity, convened by WHO, have been outlined in some detail elsewhere in this issue (page 237). The table of contents of the publication on the subject, recently issued by WHO, is given below:

## Part I. Report of Study Group

Report of Study Group on the Effect of Radiation on Human Heredity:

1. Introduction
2. Natural and man-made sources of ionizing radiation
3. Importance of recording radiation exposure in individuals and populations
4. Research
5. Some conclusions

Annex. List of participants.

## Part II. Papers Presented at Study Group

Damage from point mutations in relation to radiation dose and biological conditions—*H. J. Muller*

Types of mutation at known gene loci and possibility of hitherto unrecognized mutations being induced. Irradiation of animal populations: results and work needed—*T. C. Carter*

Some of the problems accompanying an increase in mutation rates in Mendelian populations—*Bruce Wallace*

Exposure of man to ionizing radiations, with special reference to possible genetic hazards—*R. M. Sievert*

Detection of induced mutations in offspring of irradiated parents—*J. Lejeune*

Gonad doses from diagnostic and therapeutic radiology—*W. M. Court Brown*

Mutation in man—*L. S. Penrose*

Possible areas with sufficiently different background-radiation levels to permit detection of differences in mutation rates of " marker " genes—*A. R. Gopal-Ayengar*

Comparisons of mutation rates at single loci in man—*A. C. Stevenson*

Some problems in the estimation of spontaneous mutation rates in animals and man—*James V. Neel*

Effect of inbreeding levels of populations on incidence of hereditary traits due to induced recessive mutations—*N. Freire-Maia*

Detection of genetic trends in public health—*Harold B. Newcombe*

*World Health Organization: Monograph Series No. 33*

# MEAT HYGIENE

V. E. ALBERTSEN — R. BENOÎT — T. BLOM — Phyllis G. CROFT
C. E. DOLMAN — H. DRIEUX — R. I. HOOD — M. J. J. HOUTHUIS
A. JEPSEN — H. H. JOHANSEN — M. M. KAPLAN — S. O. KOCH
G. SCACCIA SCARAFONI — G. SCHMID
F. SCHÖNBERG — H. THORNTON

" Since the dawn of history, man has had to match his wits against two-, four-, and six-legged adversaries in a struggle for existence. Once upon a time, when he won these contests, he ate as much of his opponent as he could stomach." Today, the idea of eating meat in so crude and indigestible a form is abhorrent to most people; with the development of agriculture and animal husbandry, however, mankind has come " to depend increasingly for strength and sinew upon the cooked flesh of tamed herbivores ". But the widespread use of such animals for food has brought in its train many problems. Meat is a perishable commodity and its poor handling, whether by the slaughterer, the retailer, or the housewife, is likely to result in ill health and wastage. The farmer, too, has a part to play in providing the consumer with safe and wholesome meat: he is responsible for the health and care of the animals before slaughter.

This comprehensive and well-illustrated book contains contributions from meat-hygiene experts in many parts of the world. Besides dealing with the practical health problems of the meat industry, from the ante-mortem care of slaughter animals to the hygienic processing and marketing of meat and the sanitary disposal and reclamation of by-products, it covers such wider aspects of meat hygiene as the epidemiology of meat-borne diseases; the training of meat inspectors; the current meat-hygiene practices in a number of European countries; and the special meat-hygiene problems in the tropics. In addition, much detail—on laboratory techniques for the detection of meat-borne diseases, on meat-hygiene regulations in various countries, and on design of abattoirs—is given in annexes. The book ends with a useful bibliography, classified according to the broad subjects under which the various contributions are grouped.

This monograph includes a number of the papers read at the WHO/FAO Seminar on Meat Hygiene held in Copenhagen in February 1954, as well as a review of the salient features of the discussions. These papers have, where necessary, been expanded or brought up to date, and several new articles have been contributed. The monograph is not intended as a universal guide to meat hygiene; its aim is to throw light on recent advances and problems in the many and diverse aspects of this vast subject for the benefit of the responsible authorities and students in public health and in veterinary science.

527 pages, 106 illustrations, 2 colour plates, bibliography, index

**Price: £2 10s. $10.00 Sw. fr. 30.— (clothbound)**

# MALARIA :

## Some WHO publications

### CHEMOTHERAPY OF MALARIA

by Sir Gordon COVELL, G. R. COATNEY, John W. FIELD & Jaswant SINGH
*Monograph Series*, No. 27, 1955; 123 pages, 10 figures, 14 tables, bibliography, index
17/6 $3.25 Sw. fr. 10.— (clothbound)

*This work by four eminent malariologists constitutes a critical study of the most recent antimalarial drugs. It covers a very extensive field, giving a brief general outline of the history of these drugs and examining the question of resistance to antimalarials. Each of the compounds in common use is analysed as to its chemical structure, activity, toxicity, contra-indications, dosage, absorption and elimination, and plasma concentration.*

### MALARIA CONTROL

*Bulletin of the World Health Organization*, 1954, Vol. 11, No. 4-5; 382 pages, 66 figures, 78 tables
[Articles in English or French, with detailed summary in the other language]
£1 $3.00 Sw. fr. 12.—

*This number makes a valuable contribution to the literature on malaria. It describes the new strategy in malaria control since the development in mosquitos of resistance to insecticides—a strategy by which early eradication of malaria over vast regions may be anticipated. The work provides a general picture of the present situation with regard to control by means of residual insecticides, illustrating the success and limitation of the method, and the problems it gives rise to, in many countries and territories. Other articles deal with the ineffectiveness of DDT spraying in the Jordan Valley, the effects of suspended residual spraying and of imported malaria in the USA, the resistance of* Anopheles sacharovi *to DDT and to chlordane, and the possibility of resistance to DDT by* Anopheles albimanus.

### MALARIA TERMINOLOGY

by Sir Gordon COVELL, Paul F. RUSSELL & N. H. SWELLENGREBEL
*Monograph Series*, No. 13, 1953; 82 pages, 8 figures
5/- $1.00 Sw. fr. 4.—

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